IMPROVING SOFTWARE DEFINED NETWORK EFFICIENCY WITH RANDOM FOREST MODEL

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

to

Manav Rachna International Institute of Research and Studies (Deemed to be University)

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I hereby declare that the short synopsis "**Improving Software Defined Network Efficiency with Random Forest Model**" is being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in **Computer Science and Engineering** under the School of Engineering & Technology, Manav Rachna International Institute of Research & Studies, Faridabad during the academic year 2024-2025.

It is a bona fide record of original work carried out under the supervision of **Dr. Kamlesh Sharma** Professor, CSE, FET, and has not been submitted in full or part to any other university or institute for a degree or diploma. Further, it is certified that the short synopsis is plagiarism free and the proof has been submitted.

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ABSTRACT

Software Defined Network (SDN) is a cutting-edge networking technology that includes software-based controllers that communicate with older hardware infrastructure and carry traffic directly across the network. SDN improves network governance and efficiency, increases network automation that allows engineers to instantly reroute traffic within the network, and is estimated to save money because it allows for the addition of new routes and functions without the need to purchase new hardware. Automated scaling is provided via quick scalability to distribute traffic over a wide area.

The networking industry is deeply concerned about SDN technology because of its potential to increase network scalability and agility. SDN is the technology that abstracts the control plane from the underlying network hardware, enabling centralized management and programmability of network resources. OpenFlow protocol is used to implement this control and data planes: OpenFlow Protocols, adaptability, and quick network and communication display. An automated network protocol for SDN is called OpenFlow. Switch and controller communication is facilitated by the SDN component OpenFlow. Given that the aforementioned network requirement is subject to sudden changes, OpenFlow offers a consistent deployment path for clustered programmable networks by separating the network device architecture from the core hardware. A competent data center switch called OpenFlow protocol enables network connection via a central controller. Apply packet lookup and pass once in accordance with group tables and additional discharge. OpenFlow works within the context of SDN control and data separation, flow table, controller, protocol, flow table modification, flow installation and packet forwarding, and Centralized network intelligence.

The research is divided into three phases: the first covers the various uses of SDN, the second phase addresses various problems or issues/challenges faced and the difficulties encountered in the third phase such as the models/methods/algorithms analysis and conclusion. Furthermore, many inadequacies in current SDN and alternative alternatives have been noted. The current methods: SDN based (Quality of Experience) QoE Serv, (Long long-term evaluation Standard) LTE Architecture, (Over The Top) OTT providers; Cellular SDN ; Vehicle Ad-hoc network (VANET); Software Defined Network (SDN); Wireless Sensor network (WSN); Utilizing Road Side Units (RSU); The gaps in network performance, efficiency, and cost have been filled by SOS (Save Our Souls) services, Mininet, Revolutionary Youth Union (RYU), Casual applications, security applications, simulation of urban mobility (SUMO), (), and SDN primitives like drop, forward, reflect, isolate, copy, hyper flow, elasticity, ElasticOn, ONOX.

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An algorithm that utilizes the Random Forest Model and the OpenFlow controller of SDN is suggested to create an effective network. Network efficiency is the capacity of a network to achieve its objectives, including prompt communication, error-free data transfer minimal interruption or downtime. The Random Forest method is used by the OpenFlow controller to regulate packet flow throughout the network. Optimum use of bandwidth at lowest cost for apps with a priority ranking. Scalability, performance, security, interoperability, and reliability had to be configured after deploying various controllers. The outcome will be evaluated and analyzed in the context of the OpenFlow based SDN architecture, focusing on enhancing network performance and minimizing human error.

Keywords: Software Define Network; Control plane; Controller; OpenFlow protocol; Random Forest Model;

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1. Introduction to Software Defined Network

A radical approach to network administration called Software Defined Networking (SDN) enables network managers to programmatically control, utilizing software programs, administer and enhance network resources. Traditionally, network control functions were strongly integrated into the underlying hardware, best to inflexibility and limitations in terms of adaptability and scalability. SDN allows for centralized network resource management and layout by serving the control plane's connection to the data plane.

Essentially, SDN is the separation of the control plan, is charge of deciding how traffic should be transmitted, as opposed to the data plane, which is charge of actually transmitting the traffic. This decoupling is achieved by the use of a controller which acts as the brain of the network, providing a centralized point of control. The controller uses an open protocol, like OpenFlow, to communication with network devices, allowing it to dynamically configure and manage network devices based on the requirements of the network's most popular applications.

The key advantage of the SDN is its programmability. By abstracting the control plane into software, SDN gives network managers the ability to write applications that can dynamically adjust network behavior in real-time response to shifting circumstances or application requirements. This programmability opens up a wide range of possibilities for network optimization, automation, and innovation.

SDN also offers more scalability and flexibility than traditional networking approaches. SDN enables network resources to be allocated dynamically in response to changing demand, allowing for more efficient resource utilization. Additionally, SDN simplifies network administration by offering a solitary interface for setting up and overseeing the complete network, regardless of its size or complexity.

Overall software Defined Networking represents a fundamental shift in the architecture, implementation, and management of networks. By separating the data plane from the control plane and providing a single, centralized control point. Increased agility, flexibility, and efficiency in network operations are made possible by SDN, ultimately leading to improved performance, scalability, and cost-effectiveness.

The application layer, control layer, and infrastructure layer are the three types of layers found in SDN architecture. In this manner, both northbound and southbound application programming interfaces (APIs) are used by the layers to communicate information. The

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infrastructure layer, control layer, and application layer are also referred to as the essential components of SDN. Interfaces that run northward and southerly divide these three strata apart.

1.1 Definition of SDN

The Network Paradigm has changed significantly with the introduction of Software Defined Networking (SDN), which provides increased control, scalability, and agility over network infrastructure. By decoupling network control from the underlying hardware. SDN empowers organizations to innovate, optimize, and adapt their networks to meet evolving business needs. SDN is an architecture designed to provide a specific reinforced separation between the planes' control and forwarding methods across standardized terminals. Software-defined networking, including leading businesses such as VMware, Cisco, and Juniper, is making room for cloud computing, popular resolve-based networking, and network security. The genesis of SND can be described as research collaboration surrounded by "The Stanford University of California" at Berkeley particularly supplied in the 2008 OpenFlow protocol in a definitive manner. Among the early SDN commands, OpenFlow is distinct, yet this command plays a significant role in igniting interest in lead application software decisions. Whichever vendor produced the underlying switch or router, OpenFlow Authentic is a preliminary network contact that allows a reputable entity to manage and oversee traffic between routers and switches.

"Datacenter SDN no longer attracts breathless hype and fevered expectations but the market is growing healthily, and its prospects remain robust", In a statement, the vice president of IDC of investigation for data centre networking, Brad Casemore corresponds (Worldwide Datacentre Software-Defined Networking Forecast, 2018–2022). Datacentre restoration will help maintain advancement as it feels convenient to boost SDN data centre superimposition and structures into multi-cloud utilization situations. The restoration is driven by the resolute investigation into digital transformation and ascertained by the adoption of cloud architecture.

SDN is a network architecture that uses standardized interfaces in the control plane to divide the data plane and application planes.

Component of SDN: With SDN technology, all component functions, including the data plane, are automated. This enables network administrators to programmatically and centrally administer the network. The network is orchestrated and managed by SDN

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Controller, a centralized software entity. It uses protocols to communicate with network devices, like OpenFlow providing a unified view of the entire network topology.

1.2 SDN layers

The SDN has three types of layers

Application Layer: The layer works as a typical network application like a firewall, routing algorithm, and load balancing. It also helps to solve network management problems in internet exchange points and wide networks

Control Layer: The layer is referred to as the network's brain. It enables the application to abstract from hardware. It logically computes how traffic should be forwarded.

Infrastructure Layer: The layer carries out the actual movement of data packets. The layer aids in data packet routing over the network and is made up of the actual switches from the data plane.

1.3 Important Characteristics of SDN

With the centralized state of the current SDN design with applications aid in the recovery of the critical network base. The control and data plane is divided by network agility. Every component that SDN replaces, including the capacity to build networks and ensure that applications run correctly, Having the authority to keep an eye on each destination of a frame or packet helps enforce regulations. network sizing support for many apps across all networks.

1.4 Important Features of SDN

Software Defined Networking (SDN) is a novel networking paradigm in which a single high-level software application controls the behaviour of the whole network. The Agile allows network to dynamically remove control from grant authorization for change, allowing it to adapt to changing needs. Central supervision: In this scenario, a control plane is used to centrally direct the network. There are different kinds of networking planes: data planes and control planes.

- **Data plane:** The network's data plane that controls whether traffic is sent or not. This

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is usually where forwarding tables are created. In routers, switches, firewalls, and middleboxes, the data plane is serviced as a forwarding table.

- **Control plane:** The control plane, such as network pathways and forwarding plane, is managed by the control plane. Typically, each instance of high-grade software is created in the role of controller, governing with control plane's action.

There are two kinds of working networks utilized for SDN:

- **Operational Networks:** It represents a paradigm in computer network nodes, typically routers or switches can execute user-defined programs or scripts directly within the network infrastructure. This concept aims to bring programmability and intelligence closer to the data plane, enabling dynamic adaptation of network behavior based on application requirements, traffic conditions, or other factors.
- **Network virtualization:** Network virtualization is an innovation in technology that allows the production of several virtualized network instances above a tangible network infrastructure. It abstracts the underlying physical network resources and enables the creation of logical network entities that operate independently of each other. the idea of building several distinct logical networks on top of a single, shared physical network architecture.

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2. Literature Review

2.1 Applications of SDN

Along with an explanation of SDN and its interfaces provide an extreme compilation of essential features. To map SDN interfaces and attributes with use cases, emphasizing the significance of each interface and feature for each circumstance. When considering, whether SDN is the right period for a given use case, the compass courses a capability adopted regarding SDN [1].

The Quality of Experience (QoE) function tailored for on-demand services and premium users through Software-Defined Networking (SDN). The proposed "QoE-service" leverages the global resource visibility of SDN and integrates complementary QoE metrics to ensure optimal performance for OTT applications, utilizing advanced traffic management strategies. [2].

The analytical aspect of the Internet of Things as well as each automation of SDN, contemporary research trends, and every creatively responsible element. To demonstrate how a comparison analysis of current solutions regarding SDN occupying IoT applications provides a seamless and concise view of the trend that is approaching [3]. Through improved site visitor management developed an application of traffic control and suggested a benefit of utility for the methodical arrangement of each SDN control plane [4].

To describe a Security Control model in addition to messaging their general performance and strength, OpenFlow also shows that specific Security Control components are active with primary flow protection devices and provide strong protection against SDN-enabled networks.

Protocols such as OpenFlow, Forward and Control Element Separation (FORCES), Path Computation Element Protocol (PCEP), Network Configuration Protocol (NETCONF), and Interface to Routing System (IRS) play key roles in SDN networks. Among these, the Border Gateway Protocol (BGP) stands out as a crucial enabler of network programmability in SDNs.

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The prototype's performance is assessed using metrics like Latency, Throughput, CPU consumption, and Time to Live (TTL). Simulation results reveal that SDN controllers utilizing BGP achieve an average throughput of 49.6 Gbps, a maximum latency of 7 μs, average CPU consumption of 89%, and a maximum TTL of 600 ms [24].

SDN is primarily utilized in data centers, where novel approaches are applied to enhance the efficiency of the network control plane. Through experimentation, a 28% reduction in processor energy consumption was achieved in a constant throughput scenario, compared to single-core approaches [29]. The comparative examination of several SDN applications is presented in table 1.

Table 1: Study of different SDN Applications (source: self)

S. No	Paper Title	Authors	Methodology	Research Gaps
1	A Compass Through SDN Network	Tran-Gia, Wolfgang Kellerer, Michael, Jarschel, Thomas Zinner, Tobias HobFeld,Phuoc	The use-cases are used to describe SDN.	The current research's interface verification and SDN description cannot produce the necessary efficiency
2	An SDN QoE-Service for Dynamically Enhancing the Performance of OTT applications	Konstantinos amdanis, Dimitris Tsolkas, Eirini Liotou, Georgia Tseliou	LTE architecture, SDN-based QoE services, OTT provider, and core EPC network	When choosing a path within the network, QoE-Serv is not operating smoothly for the end user
3	Software Defined Network (SDN) Based Internet of Things (IoT): A Road Ahead	Omair Ahmad Khan Abdul Wahab Ahmed, Sahrish Khan Tayyaba, Munam Ali Shah	Combining WSN_SDN, Cellular SDN, and SDN/IoT	A comparative analysis of current SDN-based IoT solutions offers a clear and concise

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				overview of emerging trends in the field
4	Software Defined Networking for Emergency Traffic Management in Smart Cities	Paladi Nicolae, and Martin Hell, Pegah Nikbakht	Roadside Units (RSU), Vehicle Ad-hoc Networks (VANETs), SOS Services, Comfort and Safety Applications, Simulation of Urban Mobility (SUMO), Mininet, and RYU	Notification messages are replaced with manipulation instructions to improve applications for self – reliant cars on the road
5	SecControl: Bridging the Gap Between Security Tools and SDN Controllers	Dinghao Wu and Li Wang	SDN primitives: copy, isolate, reflect, drop, forward, and so on. Pratyaastha, HyperFlow, DISCO, ElastiCon, and ONOX	Unable to connect SDN controllers to every area enclosed by a protection appliance
6	Improving Software Defined Network controllers in a multi-vendor environment	Bereketab Birhanu Deneke, Asrat Mulatu Beyene, Endalew Ayenew Haile	To enhance the performance of SDN controllers, BGP can be utilized to enable a multi-vendor environment, demonstrating how interoperability can be achieved without requiring infrastructure upgrades.	Simulation results indicate that SDN controllers utilizing BGP achieve an average throughput of 49.6 Gbps

2.2 SDN Challenges and Issues

Network function virtualization (NFV) and application-based software-defined networks (SDN) describe and implement every cloud model concept currently in use. While SDN aims to change how networks function, NFV provides assistance in putting up contemporary network functions in an accessible and standardized IT status. Correlative technologies like SDN and NFV don't depend on one solution over another [5].

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As of right now, a lot of the Internet's related legacy architecture are graphically installed so-called Internet configuration, this has caused major barriers regarding the implementation of IPv6 and challenges with IP multicast services. However, there are numerous reasons to expand the Internet, for example, improving routing both within and between domains for high availability of networks, granting customers complete end-to-end connection and facilitating simple dynamic QoS control for newly installed network applications. To meet these needs, in the form of data centers, cloud computing, and network virtualization, the architecture of the future, next generation Software Defined Networking (SDN) was first conceptualized on the Internet [6].

Network technologies are always critical to the success of technologies such as cloud computing. But still a sluggish pace of scalable IT infrastructure growth could provide issues with competitiveness. By introducing additional features for the complete network topology, software-defined networking, or SDN, can resolve such problems [7].

We investigated the literature and online resources for the SDN controllers that are now in use, including Floodlight, Open Daylight, Ryu, NOX, POX, and so on. Mohammad Abdul Rahman AlSheri and Shailendra Mishra outline and ascertain different placed section networks cost issues, technical ways at every location, a company independently manages structures for structure, broadcast clarity in network configuration, separate VLANs for each division, complex organization of site visitors, fixed environment access of independent with regard to useful hours, and bandwidth congestion at each division, and so on. Most of this tackle each Open flow protocol from a controller-based perspective [8].

To provide a detailed analysis of OpenFlow manager-based SDN that includes real-time remediation. Additionally, many methods for shielding each controller from related attacks have been discussed, which is thought to be a significant advancement in the field of SDN protection research [9].

SDN has introduced the challenge of optimizing energy consumption while maintaining network performance. Developing an energy-efficient solution is complex, as it requires finding the right balance between performance and energy conservation. To explores

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different methods for achieving energy efficiency in SDN, categorizing them into three main approaches: software-based, hardware-based, and hybrid [23].

Traffic measurement is a crucial technique for safeguarding SDN against significant security threats, such as DDoS attacks. Various SDN traffic measurement solutions have been classified based on the behavior of network applications. These solutions aim to enhance the security of SDN/SDCN networks through complementary approaches [26]. The comparative study of SDN difficulties and challenges is displayed in Table 2.

Table 2: SDN Challenges and Issues (source: self)

S. No	Paper Title	Authors	Methodology	Research Gaps
1	Software-Defined Networking: State of the art and Research Challenges	Abdallah Shami , Manar Jammal, Taranpreet Singh	SDN, Network as a Service (NFV), Datacenters, OpenFlow	Not having enough power to handle heavy loads and its lightweight virtualization method of getting there
2	Software-defined Networking: Challenges and Research Opportunities for Future Internet	Aniruddha, Gokhale, and Akram Hakiri,	SDN, Forwarding Plane, Control Plane, OpenFlow, Network Function Virtualization	The inability of widely used open interfaces limits network operators' ability to configure each network in relation to their surroundings
3	A Literature Review on Challenges and Effects of Software-Defined Networking	Mark Stieningera, Raphael, Horvatha Dietmar Nedbala	software-defined networking and the cloud	One of the main reasons for the delay is a certain ignorance coupled with an overly complicated integration into a traditional network
4	Software Defined Networking: Research Issues,	Mohammed Abdul Rahman AlShehri, and	OpenFlow, AHP, SDN, SDN Controller, MCDM	One of the biggest issues with SDN is

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	Challenges, and Opportunities	Shailendra Mishra		the lack of compatibility
5	OpenFlow Controller-Based SDN: Security Issues and Countermeasures	Pradeep Kumar ,and Hamza Mutaher	The following methodology is prevalent in the software-defined network. OpenFlow countermeasures, Data plane, Control plane, Security concerns, and Security issues	One of the main issues is that the OpenFlow controller is not protected
6	Energy-efficient Techniques in SDN: Software, Hardware, and Hybrid Approaches	Vikas Verma and Manish Jain	The growing adoption of SDN has created a demand for energy optimization strategies that maintain high network performance [24].	Future exploration of energy-efficient approaches in SDN holds promising opportunities, offering significant advantages for researchers entering this field
7	A Survey on SDN & SDCN Traffic Measurement: Existing Approaches and Research Challenge	MD Samiul Islam, Mojammel Hossain, Mohammed Al Mukhtar	Identify the challenges associated with SDN/SDCN traffic measurement, explore future research opportunities. [27].	Integrating ML into SDN traffic measurement solutions provides complementary benefits for securing SDN/SDCN networks

2.3 Various Models, Techniques, and Algorithms used in SDN

The class parameters are defined here. To include instances that are correctly categorized, times that are erroneously labeled, F-Measures and Accuracy. Summarized the advantages and disadvantages of applying different approaches to both small and big fact units [10].

Usage proportion, packet failure size, and transmission intermission along transmission pathway are the four features that Cui Chen-xiao and Xu Ya-bin define as being gathered from each transmission path. In addition to selecting the route having the least payload as the records flow transportation route, those four capabilities can conclude every combined

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payload for an exclusive direction by utilizing a reduced back propagation synthetic neural community model [11].

Implementation of a straightforward framework in an agency community that uses OpenFlow to collect visitor data. The datasets that could be obtained also show how many different systems research techniques could be used for the visitor's kind. These implications suggest that every data unit collected through supervised learning may fall into a particular high accuracy group [12].

A Random Forest access is characterized and trained localization through the usage of a software-defined network (SDN) foundation. The suggested version plays homey localization and uses random woodland-primarily based pass-validation of the brain to itself. The SDN foundation is in charge of keeping an eye on security risks and managing IoT appliances in parallel. Applying a signal obtained against seven unique wireless routers authorizes the system [13].

A dynamic optimization set of rules is defined here. The (Systematic Assessment of Licensee Performance) is the foundation for this. Every time a chaotic graph emerges, the Salp Swarm Optimization Algorithm (SSOA) is developed to strengthen the enforcement of every optimizer. As a consequence, controller in large-scale SDN networks, the algorithm dynamically assesses each most beneficial range related to controllers as well as top-of-the-line connections among switches [14].

An application using a dynamic load balancer technique is defined and SDN-based 3-tier data center network overcomes this type of problem. A check has been made on the use of Mininet software and Floodlight controllers, such as SDN controllers, to challenge every civilization. The Python programming language is mostly used to write applications for weight-balancing sets of rules and to sketch up network topologies. iPerf is ultimately utilized to verify network enforcement overall. The community was accepted before and after all weight-balancing regulations were completed. The testing aims to test first-class carriers in terms of bandwidth, acknowledgment time, and thresh out as well as quality of service (QoS) boundaries [15].

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A firefly optimization technique with dynamic loss restricting is defined to determine the network's shortest path between two nodes. Using Ryu controls and method of firefly optimization was provided. The result demonstrates that every source and destination's shortest path is improved when the firefly optimization algorithm is used. [16].

SDN provides more flexibility and a logically centralizing controller. With a keen eye, Ravana supports these guarantees in the event of a switch or controller malfunction. An SDN controller platform that is fault-tolerant and only processes each assignable control message once can enhance efficiency [17].

As of right now, HULA encapsulates a sizable, effective non-blocking switch. HULA is resilient to topological failures, scales to huge topologies, and is aware of congestion. Secondly, the implementation of fine-grained rules will be added by the introduction of CacheFlow, which suggests abstracting a switch with a logically unlimited rule space. CacheFlow rules combine hardware and software data routing to execute policies in a way that maximum efficiency and flexibility [18].

A potential solution is a hybrid networking environment, also known as Hybrid SDN (hSDN), where SDN functionalities are integrated while still acknowledging the presence of traditional network infrastructures. To presents a thorough, state-of-the-art survey that explores hSDN from multiple perspectives [25].

A computational grid is an integrated hardware and software infrastructure that offers reliable, consistent, widespread, and cost-effective access to advanced computational resources. It facilitates the sharing of highly controlled resources, where providers and consumers clearly define what is shared, who is permitted to access it, and the conditions under which sharing takes place. The group of individuals and/or institutions governed by these sharing rules forms what is known as a virtual organization [27].

A load balancing algorithm for IoT controllers based on data center SDN architecture is proposed. This approach utilizes a Bayesian network to predict load congestion levels, integrating a reinforcement learning algorithm to make optimal action decisions. The

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algorithm also self-adjusts parameter weights to manage controller load congestion, thereby achieving load balancing and enhancing network security and stability [28]. The table 3 shows the summary of various Models, Techniques and Algorithms used in SDN.

Table 3: Study of various Models, Techniques, and Algorithms used to solve the SDN issues (source: self)

S.No	Paper Title	Authors	Methodology	Research Gaps
1	Random Forests and Decision Trees	Nasir Ahmad, Imran Maqsood, Jehad Ali, and Rehanullah Khan	Combined with J48 and Random Forest, Decision Tree	Whenever there is a tiny dataset accessible, it causes issues
2	Research on Load Balance Method in SDN	Xu Ya-bin , and Cui Chen-xiao	OpenFlow Controller, SDN, BP Artificial Neural Network, and Load Balance	Every static load balancing technique's round robin result show that it is the worst of the bad.
3	Machine Learning in Software Defined Networks: Data Collection and Traffic Classification	Paulo Pinto, Luis Bernardo, Pedro Amaral, and Joao Dinis	SDN, ML, Data Processing, Data Analysis, and Traffic Classification	It is accessible for small businesses and campuses
4	Random forest classifier in SDN framework for user-based indoor localization	Anne Denton, Rahul Gomes, and Mostofa Ahsan	OpenWRT, OpenFlow, PSO, GSA, FPSOGSA, Random Forest, Wi-Fi, kNN, Support Vector Machines, IoT, and SDN	Not possible to determine the model's accuracy without an internet connection

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5	Chaotic salp swarm algorithm for SDN multi-controller networks January	Anastasia Vybornova, Abdelhamied, A. Ateya, and Ammar Muthanna	Placement of the controller, utilization, swarm, latency, and SDN optimization algorithm	The Non-Zero-Sum Game method, Gray Wolf Optimization (GWO), and Practical Swarm Optimization (PSO) have the poorest set of rules in terms of computation time
6	Dynamic Load Balancing Algorithm in SDN-based Data Center Networks	Jianxun Zhang, and Gudu Bekama Haile	Python, Mininet, Data Center Network, Floodlight as SDN controller, and Dynamic Load Balancing Algo	Congestion cannot be prevented while improving the use of network resources at the same time
7	Hybrid SDN Evolution: A Comprehensive Survey of the State-of-the-Art	Sajad Khorsandroo, Adrian Gallego Sanchez, Ali Saman Tosun, Jose Manuel Arco Rodrıguez, Roberto Doriguzzi-Corin	SDN functionalities are utilized while recognizing the role of existing traditional network infrastructure [26].	An extensive state-of-the-art survey that explores hSDN from multiple perspectives

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3. Description of Improving Software Defined Network Efficiency with Random Forest Model

Software Defined Network (SDN) Architecture: The framework that defines how infrastructure systems are designed, build, and managed to enable networking capabilities. A series of networked household appliances and software-based technologies can be used to accomplish this. It splits gives regular updates on the SDN networking load via the SDN control plane. [19] Below is the SDN terminology:

Network Device (ND): A device that handles packet handling and provides additional network processing. Put another way, a network accessory can be innovative in terms of the environment. Up till the traffic is maintained, the Forwarding Plane (FP) is carrying the load. The equipment administration and operation are within the purview of the Operational Plane (OP). The management plane (MP) is in charge of overseeing all network operations, including device testing and operation.

The Control Plane (CP): It decides how to operate a single or several network devices. The community devices are instructed to handle the forward packets via the manipulation plane. application (app) device on a network that used integrated services to complete a task. In addition to carrying out additional tasks, the network's service component generates one or more APIs for tasks or alternate initiation related to the same or different layers via functions. The service can be combined with other products to form a sophisticated supplier.

A representation of the communication between components is called an interface. The organization putting the policy into practice typically handles the intersection if these components are not physically located in the same place. To stop these components from coming together in the physical locality, there might be a set of guidelines or an open support software system transmission with terminal API. On extra models, Device Abstraction Layer (DAL) is installed. Given that every hardware instruction layer (HAL) is associated with a specific device, the device abstraction layer for a set amount of time this might be permitted if the device is environmental.

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Control abstraction layer (CAL): Every control abstraction layer offers information on each control plane's southbound intersection. Layer of Management Abstraction (MAL) There is a link between each management and each abstraction layer.

Since every frame of the force reference task allows ForCES to execute normalized operations, each. Every Customer Premises Satellite Interface (CPSI) has a Management Scheme Southbound Interface (MPSI) that the ForCES protocol can act on. Every ForCES prototype is most likely acquainted with the designated DAL; every pair functions with the upload plane and is in good working order. Both MAL and CAL need to be dependable in their promotion of every FORCE protocol.

Every structure can have generalized operations, like the YANG protocol (RFC6020), carried out by NETCONF, DAL. The functional plane to be exposed by DAL and MPSI is relevant to NETCONF (RFC6241). NETCONF is possible to release messages, meaning a client can request many RPCs without having to wait for messages containing RPC results. RFC 6241 defines RPC messages.

OpenFlow is a protocol that uses OpenFlow flexible switches to annotate every interface of one or more authorization services. An open flow controller assigns a unique loss switch to each entry in the flow table that corresponds to the applicants. Controllers are used to broadcast OpenFlow as a result [20]. The Open Flow protocol's manipulable OpenFlow entries. OpenFlow protocol offers all the details, including the customer's promised satellite interface and CAL, in the fine language on the bottom cover DAL for each promotional plan.

Random Forest: Established following collective learning, Random Forest is a brand derived from supervised learning algorithms. The term "ensemble learning" refers to a learning scenario in which the dominant robust prediction model is identified by combining various sets of algorithms or repeated evaluations of related algorithms. An algorithm known as the Random Forest model algorithm combines various algorithms in each equivalency class, such as several decision trees, to create what is known as a "Random Forest" tree forest. An ensemble learning technique for categorization is called Random Forest or Random Decision Forest. An expandable and easily accessible machine learning method that offers extreme outcomes and largely balanced BOLD framework control is called Random Forest. Due of its simplicity and diversity, this method is the most widely

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used. As a result, it works well for the two fundamental tasks of regression and classification. The following stages are how it operates:

- Choosing arbitrary samples from an existing dataset.
- For each sample, create a decision tree, then obtain the declared outcomes from each decision tree.
- To ensure that each announced outcome has a majority.
- Select the outcome that has the largest majority to make your final announcement.

The total quality expected values for each tree in the forest, or the overall quality expected values in the event of a range problem, can be averaged to get the ultimate cost. Every tree in every forest region is a representation of the class outcome for which the most recent report is located in the proper location. Finally, the class with a simple majority is reassured by the most recent report. A set of guidelines has been established to make Random Forest easier to use.

- There are multiple trees in the set of random forest rules and each tree is selected into a subset based on the data, the set is impartial. Reducing absolute biases concerning each algorithm is achieved by using random forest algorithms, which anticipate each energy from the "crowd".
- The set of rules is highly reliable. Even when new data is introduced into the dataset, the overall set of rules remains largely unaffected. While certain decision trees in the random forest may be influenced by the new data, it is unlikely to significantly impact the behavior of the entire ensemble, maintaining the robustness of the model.
- Having the stated capabilities allows the Random Forest method to function perfectly. In addition, the Random Forest method performs effectively even when the data is poorly accessed or lacks values.

3.1 Research Gaps

The following are the research gaps:

- While attaining the intended efficiency, the end-user experience is not seamless when it comes to the mapping of SDN and QoE-Serve interface and features.
- The typical open intersection limits the network operator's ability to modify the

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network to suit their own needs and the system's overall performance decreases with highly loads.

- The fundamental points of a delayed and incomparability issue in SDN are merely the combination into a single network.
- One of the main obstacles to achieving the required efficiency is the OpenFlow and SDN controllers' security deficiencies.
- Small datasets present a challenge, and the round robin method applied to all static load balance approaches yields the worst results.
- Just a Few Algorithms In terms of processing time, the Non-Zero-Sum Game method, Grey Wolf Optimization (GWO), and Practical Swarm Optimization (PSO) are the poorest sets of rules since they cannot handle congestion, which leads to inefficient resource consumption in addition to raising the cost of using network resources.

3.2 Problem Formulation

The efficient management of packet flow and resource utilization in SDN networks remains a significant challenge. The aim of research is to design an advanced prioritization models to monitor and optimize network performance. The proposed model will be capable of leveraging OpenFlow controller data to determine optimal resource allocation, such as bandwidth and routing paths. Additionally, the system will be capable to assess network opportunities, prevent failures, and ensure effective utilization of SDN's OpenFlow topology. The overall performance and efficiency of SDN networks will be increase.

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4. Objective of the study

- To study different prioritization models of SDN to keep an eye on packet flow over the network and resource utilization.
- Create an algorithm using the information from the SDN's OpenFlow controller employing the Random Forest Model to decide the best resources such as bandwidth and routing paths.
- To implement the algorithm to enhance the overall performance and efficiency of the network, ensuring optimal utilization of the resources.
- Examining and assessing the results of the SDN's OpenFlow network topology based on the network opportunity, prevention of network failure, and resource utilization.

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5. Research Methodology

A few techniques will be applied to improve SDN efficiency. The main techniques are described in the sections that follow. such as traffic engineering path efficiency, load balancing, routing, monitoring, management, and cloud composition.

5.1 Research Methodology

SDN is a well-known technique for accomplishing any objective. SDN is being applied to by two peer groups in general. SDN via overlay networks installed on hypervisors and SDN between current APIs. The first step in the insertion process is to implement a certain set of pre-existing functionalities on a networking device. This is usually done using more flexible systems connected via RESTful APIs, or through more conventional accessible SNMP or CLI. Figure 2 below depicts the process.

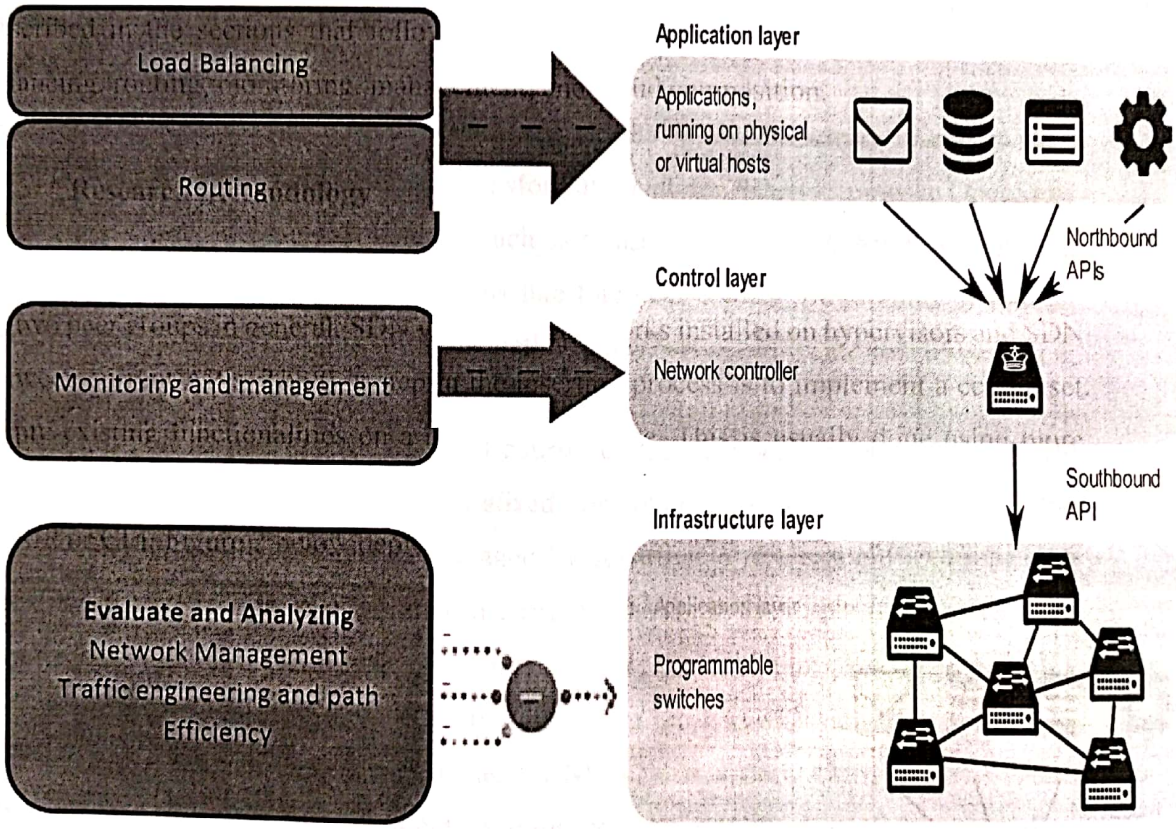

Figure 2: Research methodology process diagram

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Medium hypervisor-based superimpose networking, which includes every best physical network, is configured for communication in a different way through SDN virtualized superimpose networking. Second, the term "superimposing networking" refers to VLAN terminology and has nothing to do with P2P; it suggests alternative superimpose networks like BitTorrent and Napster.

Load Balancing: The load balancer uses certain server loading measurements to promptly react to client requests for an exact duplicate of the selected quality. The load balancing services operate superbly on inline services hosted through the datacenter. Generally, a load balancer assigns each load to link and datacenter elements in order to spread work over scheduled links; capacity is given as the lowest link cost for a certain boost measure. Load balancing is made possible by SDN, enabling granular overall activity. Every use case in data center loading is predicated on the solution balancer provided by express OpenFlow.

Routing: On a visible locked box networking facility, a true broadcast routing system operates best using the routing protocol transformation model. When it comes to OpenFlow Exchange's priority modules of control, such as transport completion, MOLD, protected routing, secure path, and protocol versions like Internet Protocol, these kinds of routing services can be completed using the SDN methodology. versions that are part of version 6.

Monitoring and measurement: SDN, of course, collects connection reports to a World Wide Web instance, particularly a centralized controller to ensure proper control. The present report is trustworthy and is managed by software to obtain a collection of data fields. Moreover, explicit management of current services at each control plane is made possible by collective representation, which facilitates efficient attestation [21].

Evaluate and analyze the working of SDN: this can offer a broad assessment and analysis of the advancements in software-defined networking (SDN). SDN is a networking method where software-based controllers or application programming interfaces (APIs) are used to regulate network traffic and connect with underlying hardware infrastructure.

Network Management: Typically, an administrator configures each network management administration after a network engineer operates it. When any other network action is

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inhibited, the network administration unit remains constant and hardly ever changes. In essence, every SDN controller chooses which network flows to prioritize and how important these flows are to each connected device. Every kind of service, including VoIP development, is built up dynamically between every phone.

Traffic Engineering and Path Efficiency: SDN in traffic engineering provides a more flexible, adaptive and programmable approach to managing network traffic. By centralizing control and providing real-time visibility, SDN can significantly contribute to optimizing path efficiency in modern networking environments.

5.2 Tools and Technologies used

Here are a few tools and technologies used to develop and implement the research topic named "Improving Efficiency of software-defined Network using Random Forest Model" which are shown below:

- Platform: Using SDN Architecture
- Model Training: The algorithm of Random Forest
- Dataset: Connect with others using the Google Application
- Tools: VMware and Mininet
- Programming Technology: Python

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6. Expected Outcome of the Research

- An effective prioritization model will be developed for SDN to monitor and manage packet flow, ensuring optimal resource utilization.

- A Random Forest Model-based algorithm that dynamically leverages OpenFlow controller data to determine the best resources, such as bandwidth and routing paths will be created, which help to improved overall performance and efficiency of SDN networks through optimized resource utilization and minimized network failures.

- Establishment of a robust evaluation mechanism to assess network opportunities, prevent potential failures, and ensure efficient use of OpenFlow network topology.

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7. References

[1] Jarschel, M., Zinner, T., Hobfeld, T., Tran-Gia, P. and Kellerer, W., 2014. Interfaces, attributes, and use cases: A compass for SDN. IEEE Communications Magazine, 52(6), pp.210-217.

[2] Liotou, E., Tseliou, G., Samdanis, K., Tsolkas, D., Adelantado, F. and Verikoukis, C., 2015, May. An SDN QoE-service for dynamically enhancing the performance of OTT applications. In 2015 Seventh International Workshop on Quality of Multimedia Experience (QoMEX) (pp. 1-2). IEEE.

[3] Tayyaba, S.K., Shah, M.A., Khan, O.A. and Ahmed, A.W., 2017, July. Software defined network (sdn) based internet of things (iot) a road ahead. In Proceedings of the international conference on future networks and distributed systems (pp. 1-8).

[4] Wang, L. and Wu, D., 2018. Seccontrol: Bridging the gap between security tools and sdn controllers. In Security and Privacy in Communication Networks: SecureComm 2017 International Workshops, ATCS and SePrIoT, Niagara Falls, ON, Canada, October 22–25, 2017, Proceedings 13 (pp. 11-31). Springer International Publishing.

[5] Jammal, M., Singh, T., Shami, A., Asal, R. and Li, Y., 2014. Software defined networking: State of the art and research challenges. Computer Networks, 72, pp.74-98.

[6] Hakiri, A., Gokhale, A., Berthou, P., Schmidt, D.C. and Gayraud, T., 2014. Software-defined networking: Challenges and research opportunities for future internet. Computer Networks, 75, pp.453-471.

[7] Horvath, R., Nedbal, D. and Stieninger, M., 2015. A literature review on challenges and effects of software defined networking. Procedia Computer Science, 64, pp.552-561.

[8] Mishra, S. and AlShehri, M.A.R., 2017. Software defined networking: research issues, challenges and opportunities. Indian Journal of Science and Technology, 10(29), pp.1-9.

[9] Mutaher, H., Kumar, P. and Wahid, A., 2018. OPENFLOW CONTROLLER-BASED SDN: SECURITY ISSUES AND COUNTERMEASURES. International Journal of Advanced Research in Computer Science, 9(1).

[10] Ali, J., Khan, R., Ahmad, N. and Maqsood, I., 2012. Random forests and decision trees. International Journal of Computer Science Issues (IJCSI), 9(5), p.272.

[11] Chen-Xiao, C. and Ya-Bin, X., 2016. Research on load balance method in SDN. International Journal of Grid and Distributed Computing, 9(1), pp.25-36.

[12] Amaral, P., Dinis, J., Pinto, P., Bernardo, L., Tavares, J. and Mamede, H.S., 2016, November. Machine learning in software defined networks: Data collection and traffic classification. In 2016 IEEE 24th International conference on network protocols (ICNP) (pp. 1-5). IEEE.

[13] Gomes, R., Ahsan, M. and Denton, A., 2018, May. Random forest classifier in SDN framework for user-based indoor localization. In 2018 IEEE International Conference on Electro/Information Technology (EIT) (pp. 0537-0542). IEEE.

[14] Ateya, A.A., Muthanna, A., Vybornova, A., Algarni, A.D., Abuarqoub, A., Koucheryavy, Y. and Koucheryavy, A., 2019. Chaotic salp swarm algorithm for SDN multi-controller networks. Engineering Science and Technology, an International Journal, 22(4), pp.1001-1012.

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[15] Haile, G.B. and Zhang, J., Dynamic Load Balancing Algorithm in SDN-based Data Center Networks. International Journal of Engineering Research & Technology (IJERT), pp.2278-0181.

[16] Katta, N., Zhang, H., Freedman, M. and Rexford, J., 2015, June. Ravana: Controller fault-tolerance in software-defined networking. In Proceedings of the 1st ACM SIGCOMM symposium on software defined networking research (pp. 1-12).

[17] Obaida, T.H. and Salman, H.A., 2022. A novel method to find the best path in SDN using firefly algorithm. Journal of Intelligent Systems, 31(1), pp.902-914.

[18] Katta, N.P.K., 2016. Building efficient and reliable software-defined networks (Doctoral dissertation, Princeton University).

[19] Casado, M., M. J. Freedman, J. Pettit, J. Luo, N. McKeown, and S. Shenker, "Ethane: Taking Control of the Enterprise," in SIGCOMM, Aug. 2007.

[20] Scott, C., A. Wundsam, B. Raghavan, A. Panda, A. Or, J. Lai, E. Huang, Z. Liu, A. El-Hassany, S. Whitlock, H. Acharya, K. Zarifis, and S. Shenker, "Troubleshooting Blackbox SDN Control Software with Minimal Causal Sequences," in SIGCOMM, Aug. 2014.

[21] Koponen, T., M. Casado, N. Gude, J. Stribling, L. Poutievski, M. Zhu, R. Ramanathan, Y. Iwata, H. Inoue, T. Hama, and S. Shenker, "Onix: A Distributed Control Platform for Large-scale Production Networks," in OSDI, Oct. 2010.

[22] Berde, P., M. Gerola, J. Hart, Y. Higuchi, M. Kobayashi, T. Koide, B. Lantz, B. O'Connor, P. Radoslavov, W. Snow, and G. Parulkar, "ONOS: Towards an Open, Distributed SDN OS," in HotSDN, Aug. 2014

[23] Verma V. and Jain M.,2024. Energy-efficient Techniques in SDN: Software, Hardware, and Hybrid Approaches. Philippine Journal of Science. ResearchGate DOI: 10.56899/153.01.01. https://www.researchgate.net/publication/377443686

[24] Deneke B., Beyene A. M., Haile E. A. 2024. Improving Software Defined Network controllers in a multi-vendor environment. Heliyon. ScienceDirect. http://creativecommons.org/licenses/by-nc-nd/4.0/

[25] Khorsandroo S, Sanchez A.G. A., Tosun A. S., 2021. Hybrid SDN Evolution: A Comprehensive Survey of the State-of-the-Art https://doi.org/10.1016/j.comnet.2021.107981.

[26] Islam MD.S., Hossain M., AlMukhtar M. 2022. A Survey on SDN & SDCN Traffic Measurement: Existing Approaches and Research Challenge. arXiv:2206.

[27] Rathore N.2017 A Review Towards: Load Balancing Techniques. i-manager s Journal on Power Systems Engineering. DOI: 10.26634/jps.4.4.11397.

[28] Liang Siyuan, Jiang Wenli, Zhao Fangli, Zhao Feng. 2020. Load Balancing Algorithm of Controller Based on SDN Architecture Under Machine Learning. Journal of Systems Science and Information. Vol. 8, No. 6, pp. 578–588. DOI: 10.21078/JSSI-2020-578-11

[29] Tadeu F. Oliveira, Samuel Xavier-de-Souza, Luiz F. Silveira. 2021. Improving Energy Efficiency on SDN Control-Plane Using Multi-Core Controllers. Energies. doi.org/10.3390/en14113161

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